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# A New Substance to Substance Joining Technology for Glasses

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**Abstract**

Currently substance-to-substance joining procedures (bonding, soldering, welding) create an adhesive bond with filler materials. For glasses these procedures are only applicable with restrictions. Therefore the aim was the development of a new force-time-controlled substance-to-substance joining procedure without filler material. During a thermal treatment a dynamic force affects the parts to be joined. This force is transmitted to the joining parts through their rotation energy homogeneously and enables a joining of large surfaces without undesired pressure peaks. The monolithic joined body gets unstressed in a subsequent cooling regime. Significant advantages of this technology are the low-stress joining of glasses without filler materials and a combinability of different glasses.

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*Keywords:* glass; joining procedure; centrifugal force; diffusion; force-time-controlled

## 1. Introduction

Substance-to-substance joining procedures such as bonding, soldering and welding are characterised by the fact that a base material and a filler material create an adhesive bond [1 - 4]. However, for glasses, especially optical glasses, these procedures are only applicable with restrictions. When optical surfaces are bonded, the adhesive layer can lead to wedge errors and thus to a modification of optical characteristics. Soldering can only be used with optically non-effective surfaces. Glasses are preferably welded through laser beam welding and similar materials are joined. Diffusion welding is used for planar joints. The joining takes place at a material-specific temperature and a uniaxial surface pressure. The joining of structured surfaces is possible only to a very limited extent and rotation-symmetric surfaces cannot be joined at all.

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## 2. Experiments

The new joining procedure enables a substance-to-substance joining of two or more elements consisting of similar or dissimilar materials by means of a controlled force without additional filler materials. The joint is created through the generation of a diffusion zone (interface). A dynamic force is exerted on the parts to be joined during a thermal treatment. In contrast to conventional procedures (e.g. bonding, soldering, diffusion welding), the force is transmitted to the joining parts through their rotation energy resulting in a homogeneous effect over the entire sample. This also enables a joining of large surfaces without undesired pressure peaks. The strength of force is variable and can be controlled during the process. The force is transmitted to defined test surfaces depending on the positioning of the material samples (axial/abaxial), which allows a joining of planar as well as structured surfaces. An axial positioning of the test pieces enables an additive-free joining of rotation-symmetric surfaces for the first time. Embedding the joining parts in a mould guarantees a defined sample position at process temperatures at the threshold to plastic deformation and beyond. The monolithic joined body gets unstressed in a subsequent cooling regime. Significant advantages of this procedure are the low-stress joining of glasses and combinability of different glasses. This article introduces joining examinations of the glass combination LLF1 (extra light flint, Co. Schott AG) and SF5 (heavy flint, Co. Schott AG). Ring samples (external diameter 30 mm, internal diameter 20 mm) and core samples were made of LLF1-glass and SF5-glass for the joining of a rotation-symmetric assembly (fig. 1). A combination of both glasses was always used as joining partners.

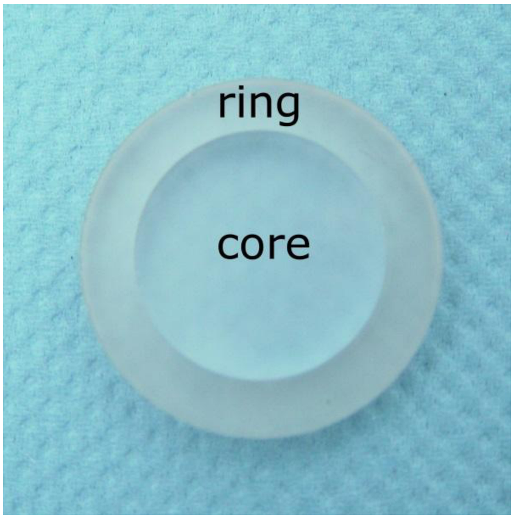


Fig. 1. Toroidal-core-sample.

The joining procedure was carried out in the transformation range of the glasses between 430 °C and 475 °C ($T_g$ LLF1 431 °C; $T_g$ SF5 425 °C). The effective centrifugal force on the joining surfaces was ca. 0.7 N, this equals a centrifugal acceleration of ca. 12 G. After heating the joining partners up to the selected process temperature a holding phase of 3-12 hours under the influence of the centrifugal force followed. Afterwards the test samples were cooled down in a multistage process. The joining procedure was carried out in the transformation range of the glasses between 430 °C and 475 °C ($T_g$ LLF1 431 °C; $T_g$ SF5 425 °C). The effective centrifugal force on the joining surfaces was ca. 0.7 N, this equals a centrifugal acceleration of ca. 12 G. After heating the joining partners up to the selected process temperature a holding phase of 3-12 hours under the influence of the centrifugal force followed. Afterwards the test samples were cooled down in a multistage process.

For processing the glasses a special apparatus was developed which basically consists of two units. The first unit guarantees the rotation of the glass samples and contains a motor driving a metal shaft which protrudes into a chamber furnace. The holding device for the glass samples is centrically fixed on this shaft. The second unit serves the controlled heat treatment and consists of a chamber furnace with integrated processor for the realisation of defined heating and cooling regimes. This apparatus is shown in fig. 2.

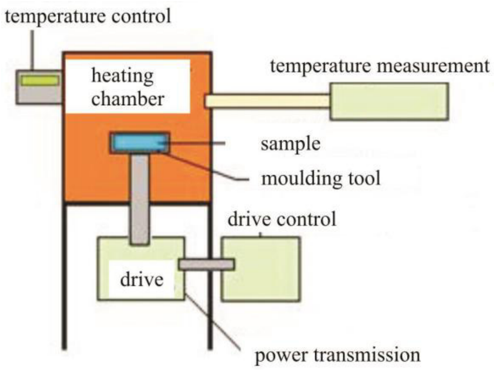


Fig. 2. Test setup.

## 3. Results

A joint of the glass parts could be achieved from a process temperature of 450 °C and a process time of 3 hours. For evaluating the joints, the joined components were cut in the middle and the cut faces were polished. The element distribution in the joining zone was detected by means of the scanning electron microscopy and energy dispersive X-ray analysis (EDX). Figure 3 shows a line scan across the joining zone of a joined ring core sample and the distribution of important elements.

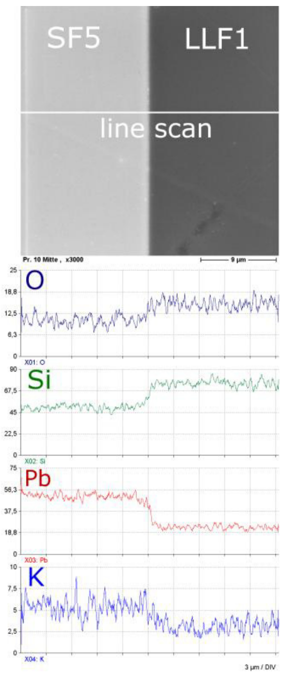


Fig. 3. Line scan of the joining zone.

The lead concentration is especially suitable for the definition of the diffusion area as it is very different in both glasses (LLF1 ca. 23 Gew%; SF5 ca. 52 Gew%). After a successful joining of the glass samples, a gradient of the lead concentration can be defined in the joining zone. For the process parameters of 450 °C, 3 hours holding time and a centrifugal force of 0.7 N a diffusion zone of ca. 8-10 µm can be detected. 4-5 µm away from the interface the lead concentration of each glass has reached its original level again. Figure 4 illustrates a typical course of the lead concentration. An increase of the holding time, temperature and force effect leads to an enlargement of the diffusion zone. A short-time heating of the samples up to temperatures of ca. 250 °C above $T_g$ prior to the actual joining process also results in a widening of the diffusion zone.

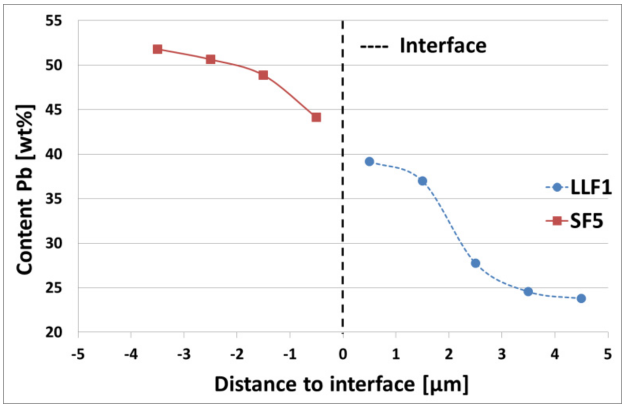


Fig. 4. Lead concentration in the joining zone.

## Conclusion

The new joining procedure enables a substance-to-substance joining of glasses with different compositions and geometries. The above-introduced test setup allowed a joining of rotation-symmetric components into a monolithic assembly. The achievable diffusion zone depends on the process time, the process temperature and the rotational force.

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